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Collaborative Biodiesel Emissions Test (CBET) Program

Proposal

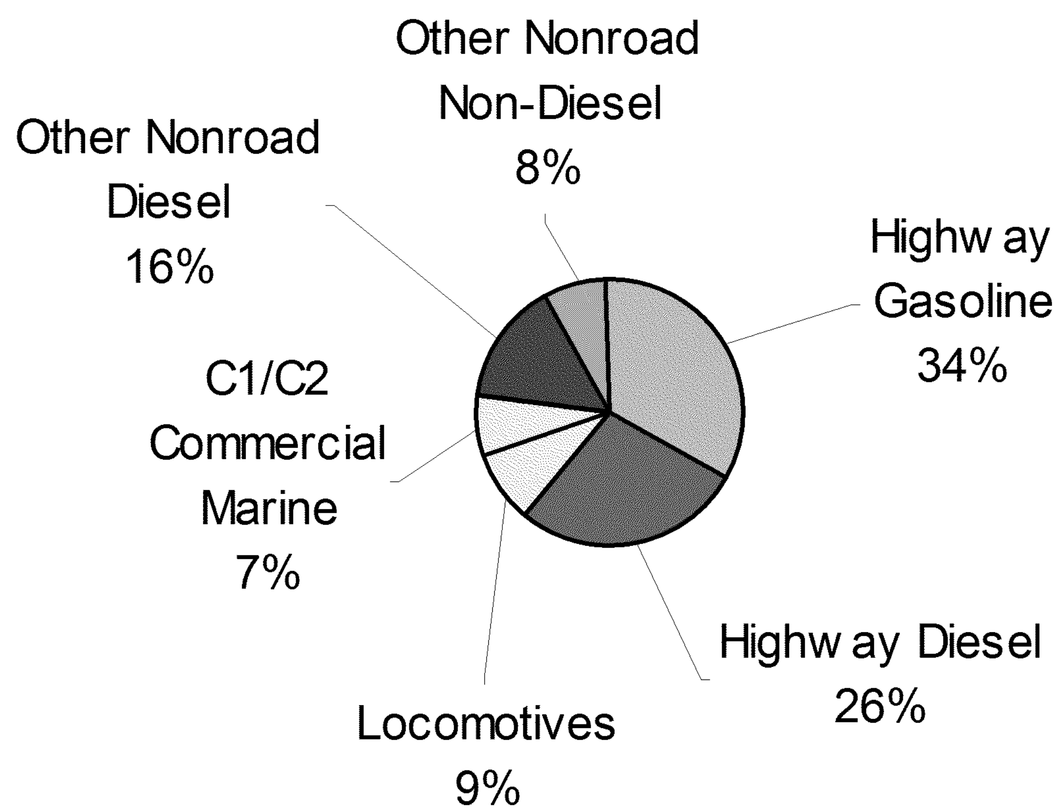
March 27, 2007

Program Objective

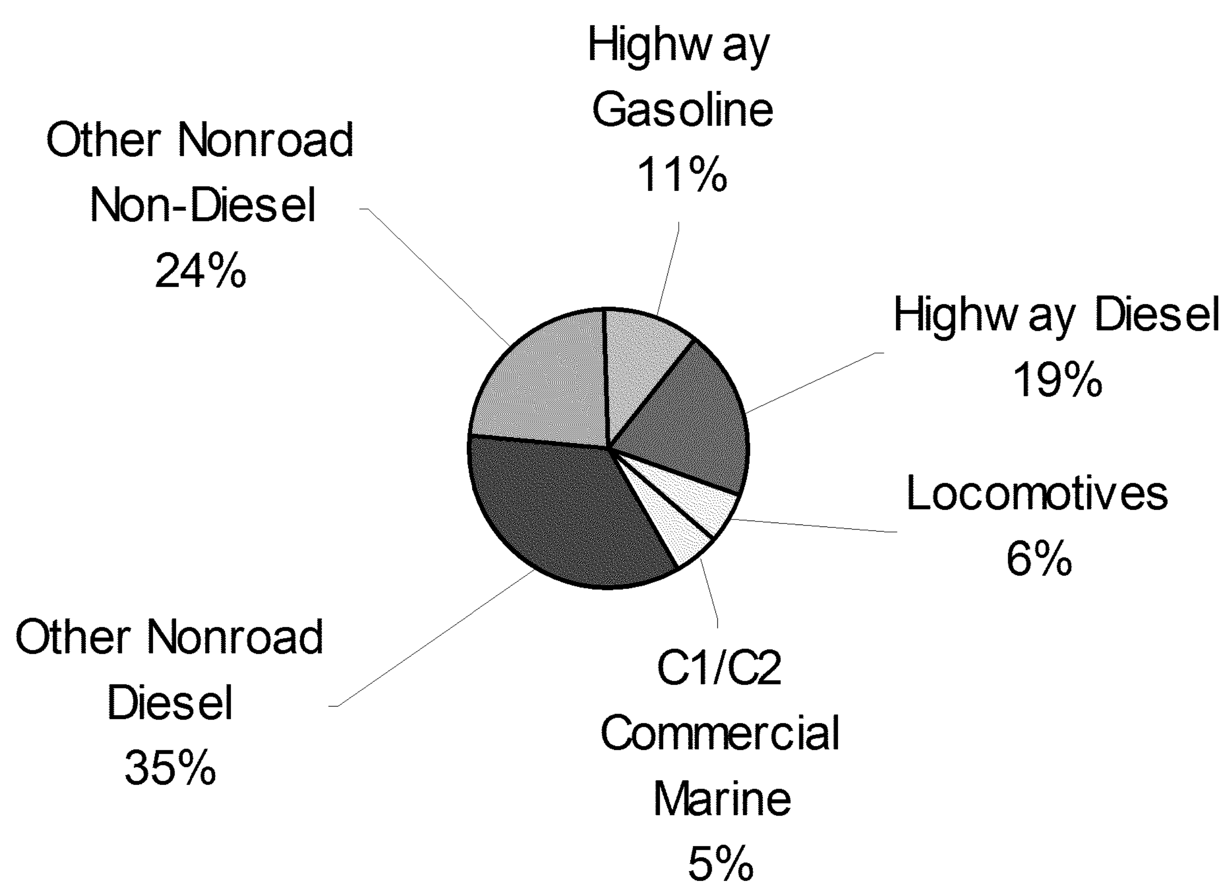
Conduct a scientific study to determine the impact of biodiesel on exhaust emissions from diesel engines

- Assess impacts of key factors:
  - Engine technology
  - Engine load / test cycle
  - Biodiesel feedstock / content
  - Base fuel properties
- Engage a broad spectrum of stakeholders
- Coordinate with CARB to ensure compatibility and synergy between CBET Program and proposed CARB Biodiesel Emissions Study

2007 US Mobile Source NOx Inventory



2007 US Mobile Source PM Inventory



Highway Diesel NOx Inventory

2007		
MY Period	% Contribution	
	Class 6&7	Class 8
pre-1991	1.5	9.0
1991 - 1993	0.8	6.6
1994 - 2001	5.7	31.0
2002 - 2006	5.8	23.3
2007	0.8	3.5
Total:	14.6	73.4

2012		
MY Period	% Contribution	
	Class 6&7	Class 8
pre-1994	1.8	12.4
1994 - 2001	4.7	25.9
2002 - 2006	4.9	20.0
2007 - 2009	2.5	11.0
2010 - 2012	0.7	2.9
Total:	14.5	72.0

Between 2007 and 2017, 85-88% of highway diesel NOx inventory will be produced by Class 6&7 and Class 8 truck engines

2017		
MY Period	% Contribution	
	Class 6&7	Class 8
pre - 1995	1.4	8.8
1995 - 2001	4.0	21.7
2002 - 2006	4.4	18.4
2007 - 2009	2.3	10.4
2010 - 2017	2.6	11.1
Total:	14.8	70.4

Highway Diesel PM Inventory

2007		
MY Period	% Contribution	
	Class 6&7	Class 8
pre -1991	4.4	23.7
1991 - 1993	1.5	5.7
1994 - 2001	3.7	13.8
2002 - 2006	5.8	24.7
2007	0.2	0.7
Total:	15.6	68.6

2012		
MY Period	% Contribution	
	Class 6&7	Class 8
pre -1994	5.0	24.9
1994 - 2001	3.7	13.2
2002 - 2006	5.6	23.5
2007 - 2009	0.5	2.0
2010 - 2012	0.8	3.3
Total:	15.6	66.9

2017		
MY Period	% Contribution	
	Class 6&7	Class 8
pre - 1995	1.8	5.2
1995 - 2001	4.1	14.5
2002 - 2006	6.7	27.7
2007 - 2009	0.6	2.4
2010 - 2017	4.0	17.0
Total:	17.1	66.7

Between 2007 and 2017, 82-84% of highway diesel PM inventory will be produced by Class 6&7 and Class 8 truck engines

2002 Highway Diesel NOx Inventory: Rural vs. Urban
50 states, DC, PR, VI

Vehicle Class	NOx Inventory					
	50 states, DC, PR, VI		Rural		Urban	
	tons/year	%	tons/year	%	tons/year	%
LDDV	7,472	0.2	3,150	**0.2**	4,322	**0.3**
LDDT	14,109	0.4	5,033	0.3	9,076	0.5
2BHDDV	98,657	2.8	41,754	2.3	56,902	3.3
LHDDV	97,293	2.8	43,748	2.4	53,545	3.1
MHDDV	397,659	11.4	182,614	**10.2**	215,045	**12.6**
HHDDV	2,759,584	78.9	1,457,390	**81.5**	1,302,194	**76.2**
BUSES	122,326	3.5	54,407	**3.0**	67,920	**4.0**
Total:	3,497,099	100	1,788,096	100	1,709,003	100

US NOx emission inventories for rural and urban areas are approximately equal

Figure 1: 2017 Nonroad Diesel NOx Inventory

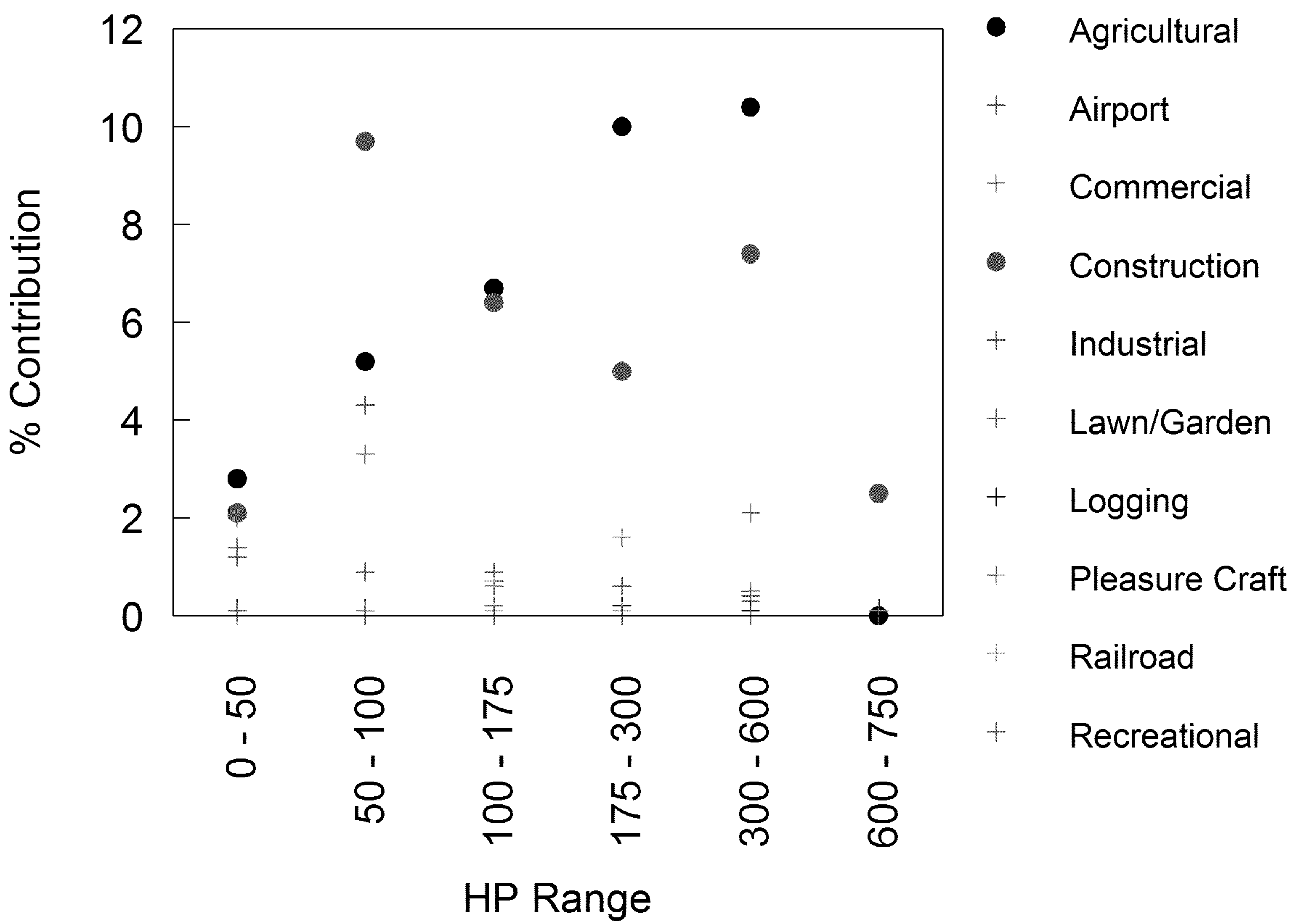
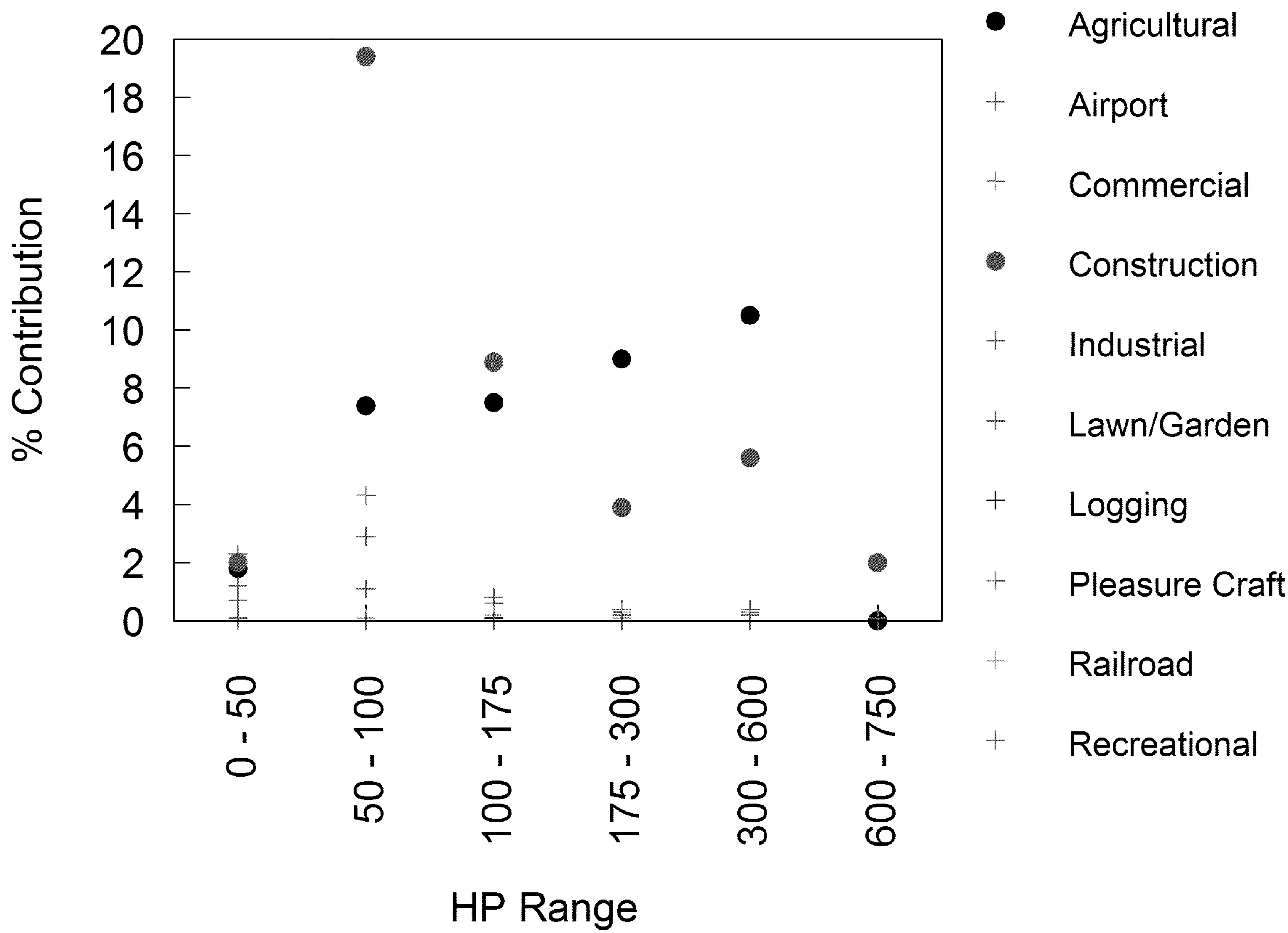


Figure 2: 2017 Nonroad Diesel PM Inventory



Nonroad Diesel NOx Inventory
Agriculture, Construction and Mining Sectors

2007			
MY Period	% Contribution		
	50 - 100 HP	100 - 175 HP	175 - 300 HP
pre -1997	5.3	5.6	6.4
1997 - 2005	6.3	8.1	10.3
2006 - 2007	1.5	1.7	1.9
Total:	13.1	15.4	18.6

2012			
MY Period	% Contribution		
	50 - 100 HP	100 - 175 HP	175 - 300 HP
pre -1997	3.4	3.1	3.4
1997 - 2005	5.9	6.3	7.5
2006 - 2010	3.6	4.2	5.2
2011 - 2012	1.1	1.3	1.2
Total:	13.9	14.9	17.3

2017			
MY Period	% Contribution		
	50 - 100 HP	100 - 175 HP	175 - 300 HP
pre -1997	2.2	2.0	2.1
1997 - 2005	5.3	4.6	5.3
2006 - 2010	4.1	4.0	4.7
2011 - 2017	3.3	2.7	3.0
Total:	14.9	13.4	15.0

Nonroad Diesel PM Inventory
Agriculture, Construction and Mining Sectors

2007			
MY Period	% Contribution		
	50 - 100 HP	100 - 175 HP	175 - 300 HP
pre -1997	12.1	6.8	7.6
1997 - 2005	9.1	6.3	6.7
2006 - 2007	1.2	1.5	1.6
Total:	22.4	14.6	15.8

2012			
MY Period	% Contribution		
	50 - 100 HP	100 - 175 HP	175 - 300 HP
pre -1997	8.7	4.0	4.2
1997 - 2005	9.8	5.4	5.1
2006 - 2010	4.8	5.5	4.9
2011 - 2012	1.2	1.2	0.2
Total:	24.6	16.1	14.3

2017			
MY Period	% Contribution		
	50 - 100 HP	100 - 175 HP	175 - 300 HP
pre -1997	6.7	2.5	2.8
1997 - 2005	10.7	4.8	4.1
2006 - 2010	7.1	6.8	5.6
2011 - 2017	2.3	2.3	0.5
Total:	26.7	16.5	13.0

Emissions Control Technology

HD Highway Diesel Engines	
Pre - 1994	Baseline
1994 - 2001	High pressure FIE, combustion system enhancements, electronic engine control, aftercooling
2002 - 2006	EGR, Acert
2007 - 2009	EGR, PM trap
2010 +	EGR, PM trap + (LNT or urea SCR or ?

Emissions Control Technology (Cont'd)

50 – 300 hp Nonroad Engines			Technology
50 – 100 hp	100 – 175 hp	175 – 300 hp	
pre - 1998	pre - 1997	pre - 1996	Baseline
Tier 1/Tier 2 1998 - 2007	Tier 1/Tier 2 1997 - 2006	Tier 1/Tier 2 1996 - 2005	Combustion System enhancements
Tier 3 2008 – 2011 or skip to Tier 4	Tier 3 2007 - 2011	Tier 3 2006 - 2010	EGR, Acert
Tier 4 2012 +	Tier 4 2012 +	Tier 4 2011 +	EGR, PM trap + (LNT or ?)

Test Engines and Vehicles

- Test engines and vehicles to represent in-use fleet
  - Past and state-of-the-art technology
    - MY 2010+ technology prototypes may not be available for testing in this program or representative of future production
  - Both highway and nonroad
  - Focus on Class 6&7 and Class 8 highway engines
  - Include 50-300 HP nonroad agricultural, construction and mining engines
  - Include LD vehicles
- Selection of individual test engines and vehicles based on production volume, diversified to include multiple manufacturers
- Technologies to include: Non-EGR, Acert, EGR, EGR/PM trap, urea SCR (LD only), NOx trap, other?

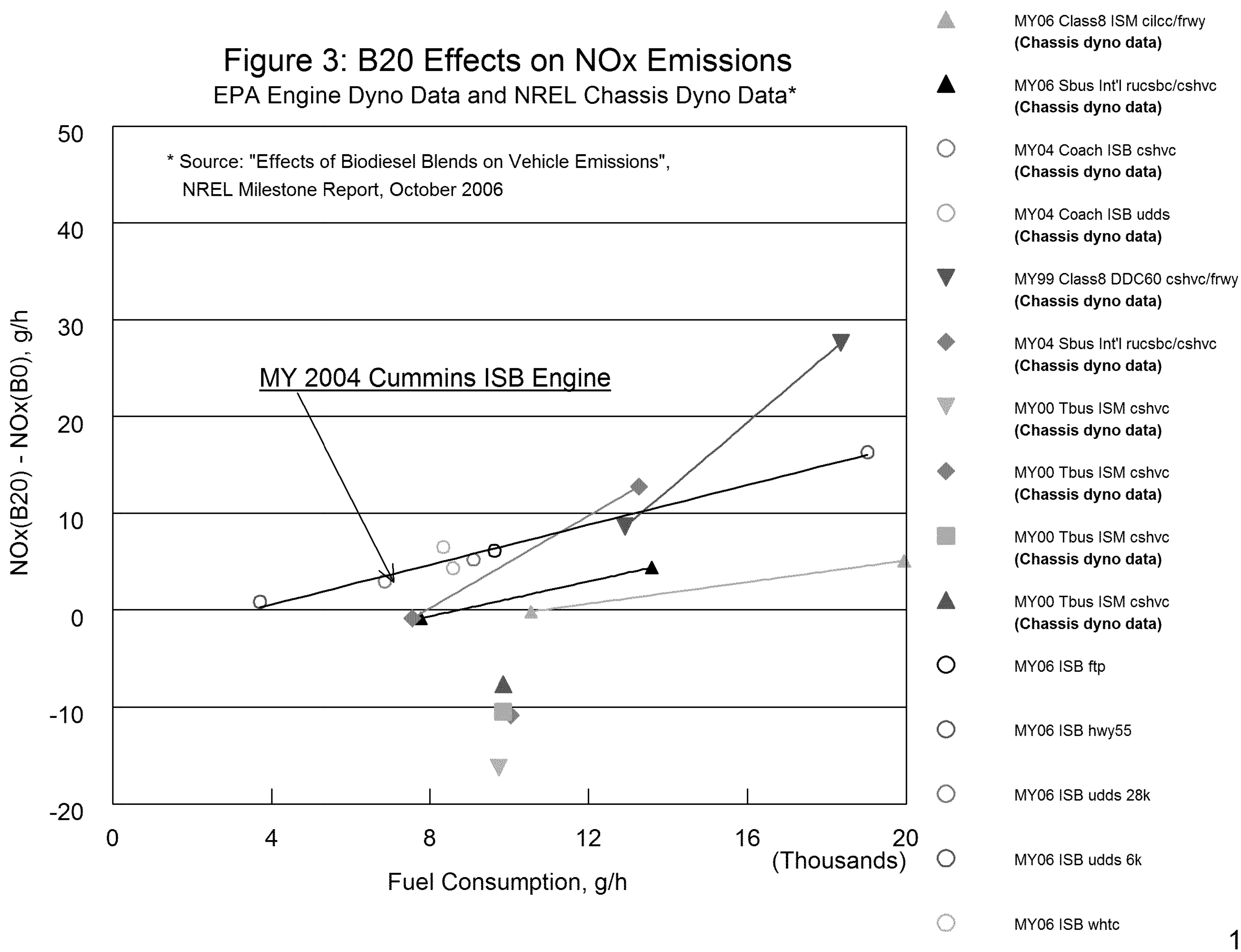


Figure 3: B20 Effects on NOx Emissions
EPA Engine Dyno Data and NREL Chassis Dyno Data*
* Source: "Effects of Biodiesel Blends on Vehicle Emissions",
NREL Milestone Report, October 2006
MY 2004 Cummins ISB Engine
NOx(B20) - NOx(B0), g/h
50
40
30
20
10
0
-10
-20
0
4
8
12
16
20
(Thousands)
Fuel Consumption, g/h
MY06 Class8 ISM cilcc/frwy
(Chassis dyno data)
MY06 Sbus Int'l rucsbc/cshvc
(Chassis dyno data)
MY04 Coach ISB cshvc
(Chassis dyno data)
MY04 Coach ISB udds
(Chassis dyno data)
MY99 Class8 DDC60 cshvc/frwy
(Chassis dyno data)
MY04 Sbus Int'l rucsbc/cshvc
(Chassis dyno data)
MY00 Tbus ISM cshvc
(Chassis dyno data)
MY00 Tbus ISM cshvc
(Chassis dyno data)
MY00 Tbus ISM cshvc
(Chassis dyno data)
MY00 Tbus ISM cshvc
(Chassis dyno data)
MY06 ISB ftp
MY06 ISB hwy55
MY06 ISB udds 28k
MY06 ISB udds 6k
MY06 ISB whtc

Figure 4: B20 Effects on NOx Emissions

EPA Engine Data and NREL Chassis Dyno Data*

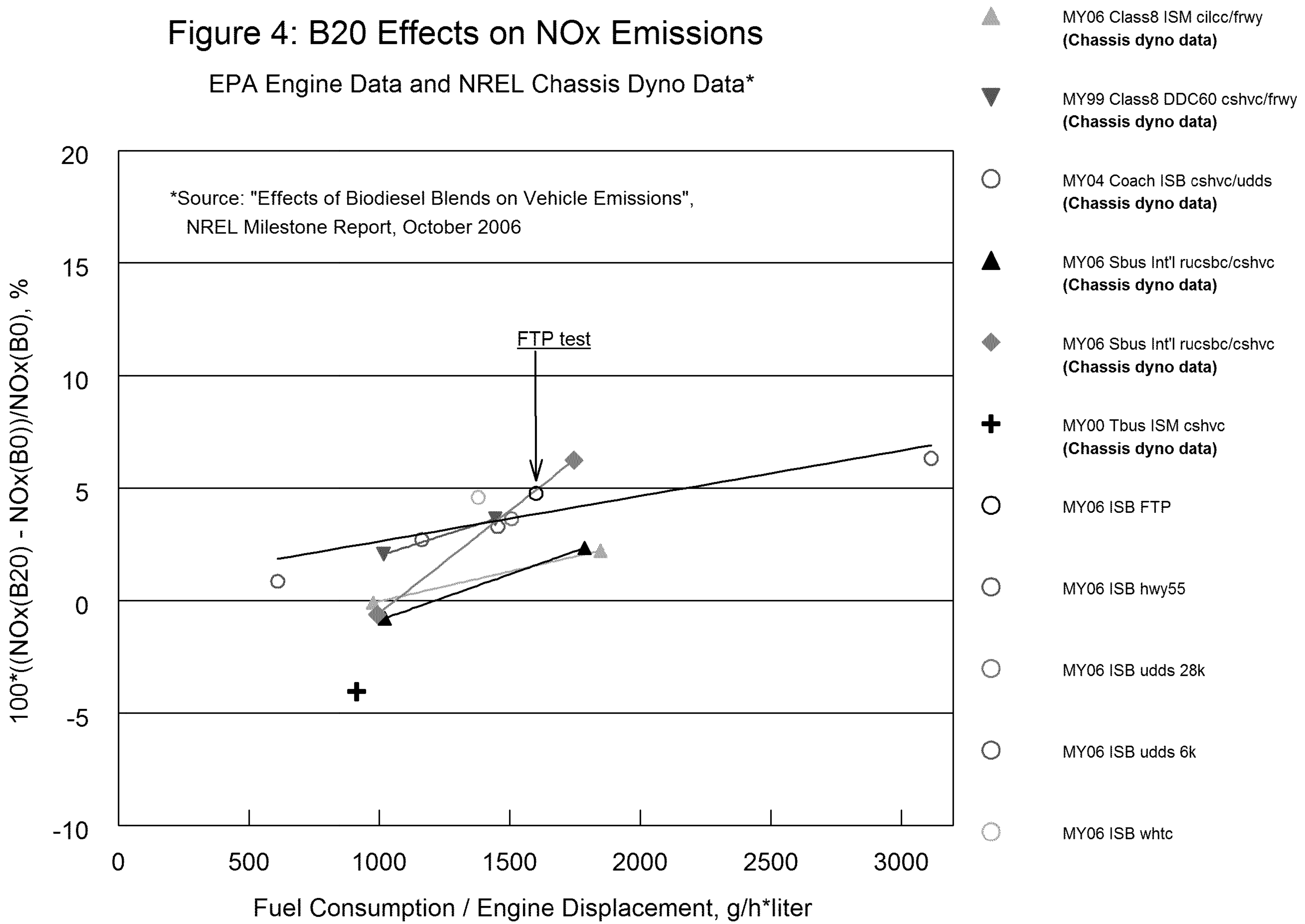


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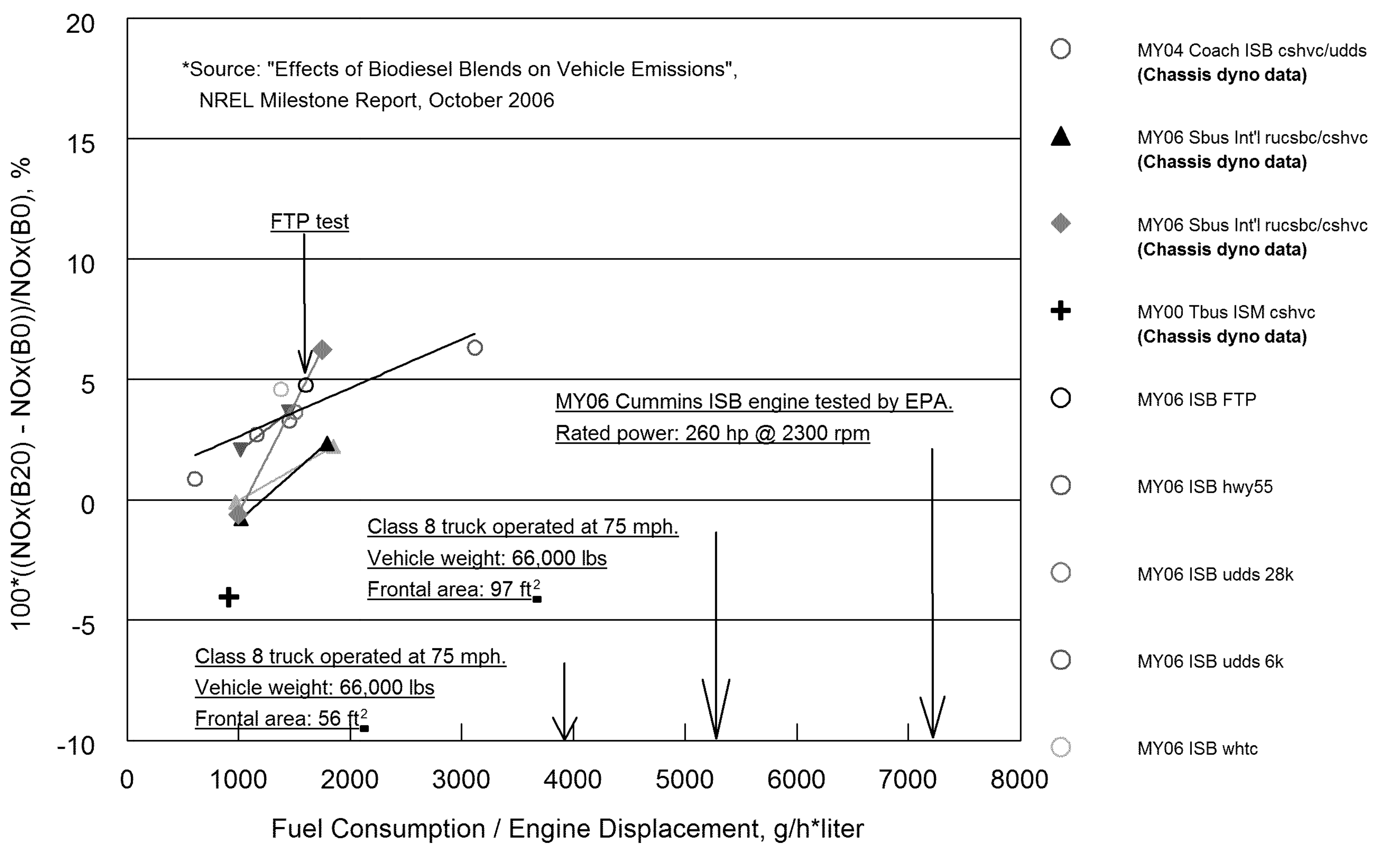
Figure 5: B20 Effects on NOx Emissions

EPA Engine Data and NREL Chassis Dyno Data*



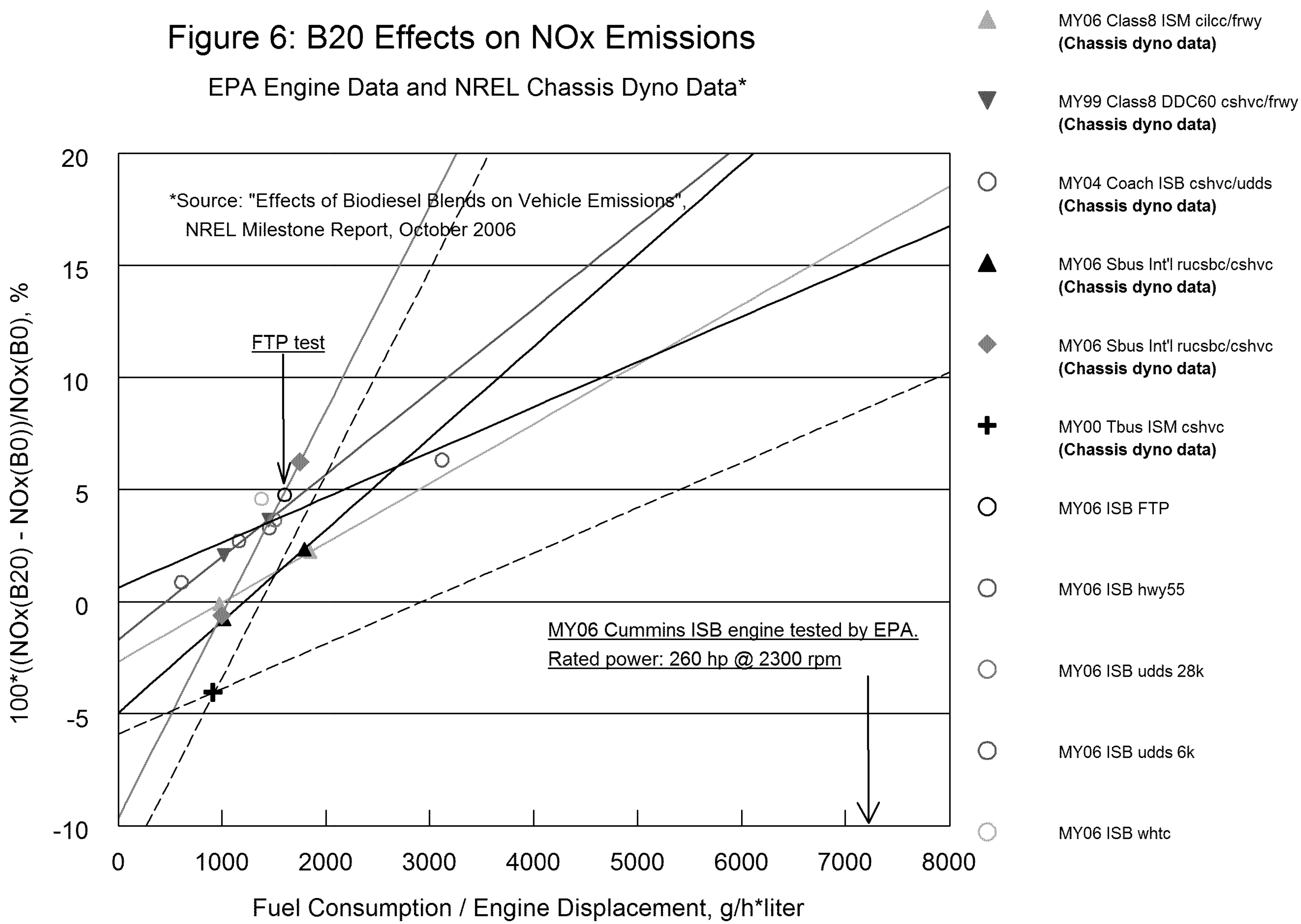


Figure 6: B20 Effects on NOx Emissions
EPA Engine Data and NREL Chassis Dyno Data*
*Source: "Effects of Biodiesel Blends on Vehicle Emissions", NREL Milestone Report, October 2006
FTP test
MY06 Cummins ISB engine tested by EPA.
Rated power: 260 hp @ 2300 rpm
100*((NOx(B20) - NOx(B0))/NOx(B0), %
20
15
10
5
0
-5
-10
0
1000
2000
3000
4000
5000
6000
7000
8000
Fuel Consumption / Engine Displacement, g/h*liter
MY06 Class8 ISM cilcc/frwy (Chassis dyno data)
MY99 Class8 DDC60 cshvc/frwy (Chassis dyno data)
MY04 Coach ISB cshvc/udds (Chassis dyno data)
MY06 Sbus Int'l rucsbc/cshvc (Chassis dyno data)
MY06 Sbus Int'l rucsbc/cshvc (Chassis dyno data)
MY00 Tbus ISM cshvc (Chassis dyno data)
MY06 ISB FTP
MY06 ISB hwy55
MY06 ISB udds 28k
MY06 ISB udds 6k
MY06 ISB whtc

Number of Test Engines

The required number of test engines was estimated as follows:

- EPA NVFEL engine data* and NREL chassis dyno data** generated on B20 were utilized as the basis of analysis
- Fuel consumption rates for each engine were normalized by dividing them by engine displacement (Figures 4 and 5)
- NOx emission rates for each engine were normalized by expressing them in % (Figures 4 and 5)
- The resulting %ΔNOx = f(fuel consumption per unit displacement) relationships were used in further analysis, assuming they were linear over the range of interest (Figure 6)
  - For transit buses tested by NREL, the range of positive responses was defined by the highest and lowest slopes observed in the data set

* Preliminary Biodiesel Investigation, December 2006/January 2007

** Source: "Effects of Biodiesel Blends on Vehicle Emissions", NREL Milestone Report, October 2006

Number of Test Engines (Cont'd)

- Monte Carlo simulations were performed to generate multiple %ΔNOx = f(fuel consumption per unit displacement) samples of various sizes (9 – 30)
- For each sample size, the results of the simulations were regressed to produce a single trend line representing the aggregate effect
- Tests were performed to answer the following questions:
  - Is the aggregate slope significantly different from 0?
    - Results of simulations are statistically significant, even for the smallest sample size considered
  - Is the %ΔNOx for the FTP cycle statistically different from 0?
    - This test is the limiting factor in estimating the required number of test engines
    - The results of this test were presented in terms of the following risks:
      - False positive: We conclude that %ΔNOx for the FTP cycle is statistically different from 0 when it is not
      - False negative: We conclude that %ΔNOx for the FTP cycle is not statistically different from 0 when it is

Number of Test Engines (Cont'd)

Risk of False Positive*	Risk of False Negative**				
	9 engines	15 engines	18 engines	21 engines	30 engines
5%	60%	50%	20%	8%	3%
10%	40%	35%	13%	5%	1%

Recommendation: Test a minimum of 18 engines to limit the risk of false positive to 10% and the risk of false negative to 13%

* Risk of false positive assumes that $\%\Delta NOx \leq 2.0\%$ or $\geq -2.0\%$ (Two-tailed test)

** Risk of false negative assumes that $\%\Delta NOx \geq 2.0\%$ or $\leq -2.0\%$ (Two-tailed test)

Test Engines/Vehicles by Technology

HD Highway Engines			50 – 300 HP Nonroad Engines		LD Vehicles	
Emissions Control Technology (MY)	# of Test Engines		Emissions Control Technology	# of Test Engines	Emissions Control Technology	# of Test Engines
	Class 6&7	Class 8				
1994 - 2001	3*	3*	Tier 1/Tier 2	1	-	-
2002 - 2006	3*	3*	Tier 3	2 (incl. one 50-100 HP engine)	-	-
2007 – 2009 (PM traps)	3* (incl. Cummins LNT)	3*	-	-	-	-
2010 + (PM traps; LNTs or urea SCR or ?)	-	-	-	-	Tier 2	3 (incl. urea SCR and LNT)

* The actual number of engines in each category and selection of makes and models will be defined in consultation with engine manufacturers

Test Engines/Vehicles

- Eighteen highway engines needed to define the biodiesel NOx effect
  - This number of engines needed to optimize experimental design
    - Maximize likelihood of successful outcome and minimize test time and cost
  - Focus on MY 1994 through 2009 engines
  - Use remanufactured MY 1994 – 2001 engines
  - Consider use of late MY engines tested in CRC ACES Program
- One Tier 1/Tier 2 and two Tier 3 nonroad engines
  - NOx effects expected to be comparable to highway engines equipped with similar emissions control technology
  - PM emissions will likely not be comparable to highway engine results in transient tests
  - Expect to extrapolate biodiesel emissions effects from highway engines and apply them to nonroad engines, unless testing of the three nonroad engines indicates otherwise
- Three Tier 2 LD test vehicles
  - LNT
  - Urea SCR
  - Other ?

Test Cycles and Test Replicates

- The number of test cycles to be used in this program was established using the following criteria:
  - A minimum of 3 test cycles are required to test linearity of the ΔNOx = f(ACP)* relationship
  - A maximum of 4 transient test cycles can be completed in an engine test cell on 2 fuels (each) in the course of a single day
- The required number of test replicates was determined as the minimum sample size needed to preserve statistical significance of ΔNOx = f(ACP) regressions at $p \leq 0.05$
  - Utilized test data generated recently by EPA NVFEL and NREL** as basis for analysis
  - Assumptions:
    - Biodiesel effect on % change in NOx emissions does not vary with emissions control technology
    - For any test cycle, the variability (standard deviation) of NOx emission results is the same for 2004 and 2007 MY HD Diesel engines
    - Biodiesel effect on NOx is directly proportional to BXX level

* ACP: Average Cycle Power

** "Effects of Biodiesel Blends on Vehicle Emissions", NREL Milestone Report, October 2006

Test Cycles and Test Replicates (Cont'd)

- The analysis:
  - Using EPA NVFEL data, slopes of $\Delta NOx = F(ACP)$ relationships were calculated for 3 test cycles (UDDS 6k, FTP and HWY55) and 4 test cycles (UDDS 6k, WHTP, FTP and HWY55)
  - 2, 3 or 4 observations were sampled at random from B0 and B20 test replicates for each test cycle, for a total of 7 sets
  - B0 observations were averaged and subtracted from B20 observations for each test cycle and each of seven sets
  - Seven $\Delta NOx = f(ACP)$ regressions were defined both for the 3- and 4-test cycle cases and their statistical significance determined at $p \leq 0.05$ level
  - The number of test cycles and replicates was deemed sufficient for use in this program if all seven regressions were statistically significant
  - This procedure was repeated for slopes adjusted to account for engine to engine variability and changes in NOx standards

Figure 7: B20 Effects on NOx Emissions
MY 2006 Cummins ISB Engine

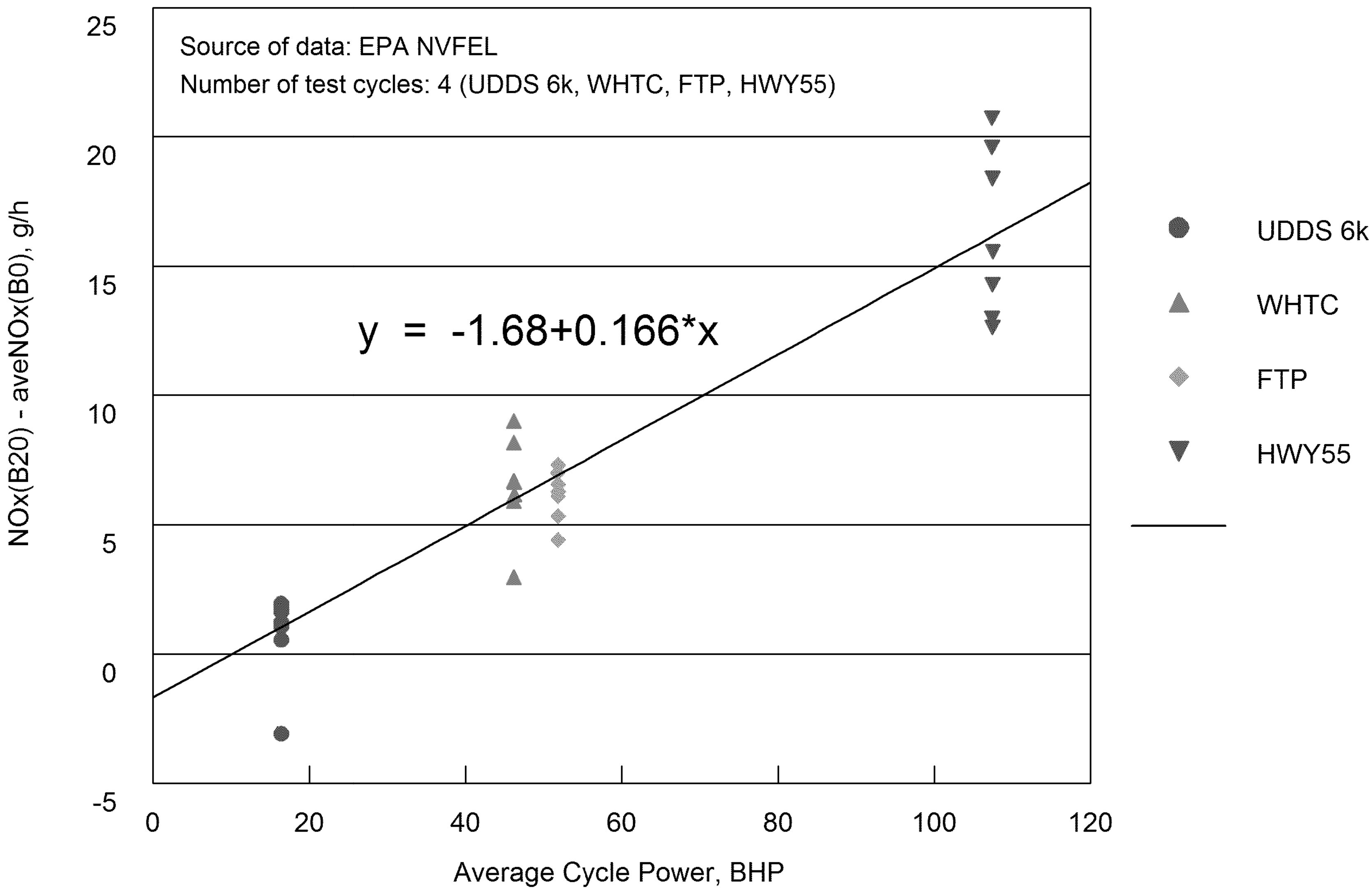


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Figure 8: B20 Effects on NOx Emissions

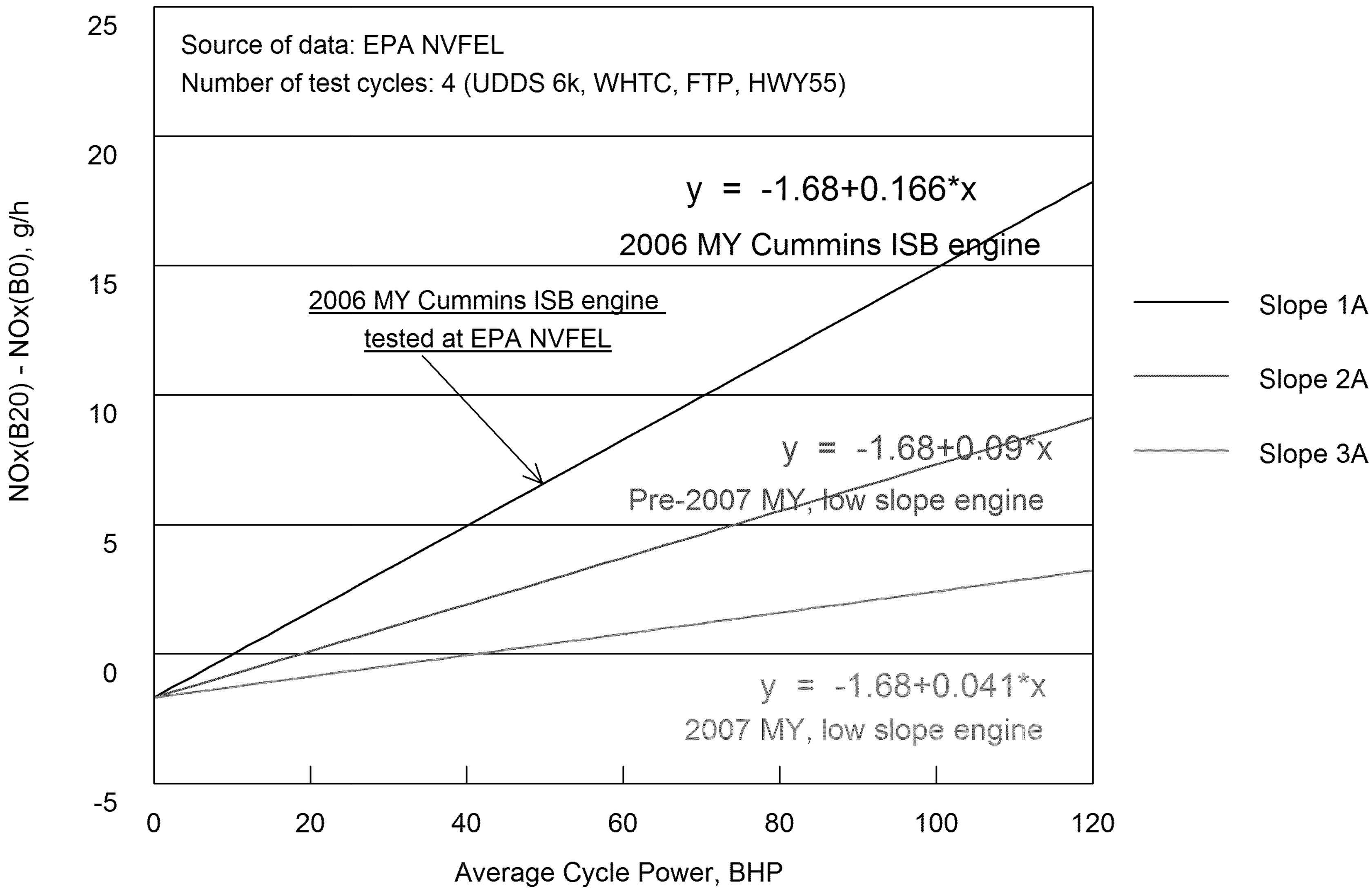
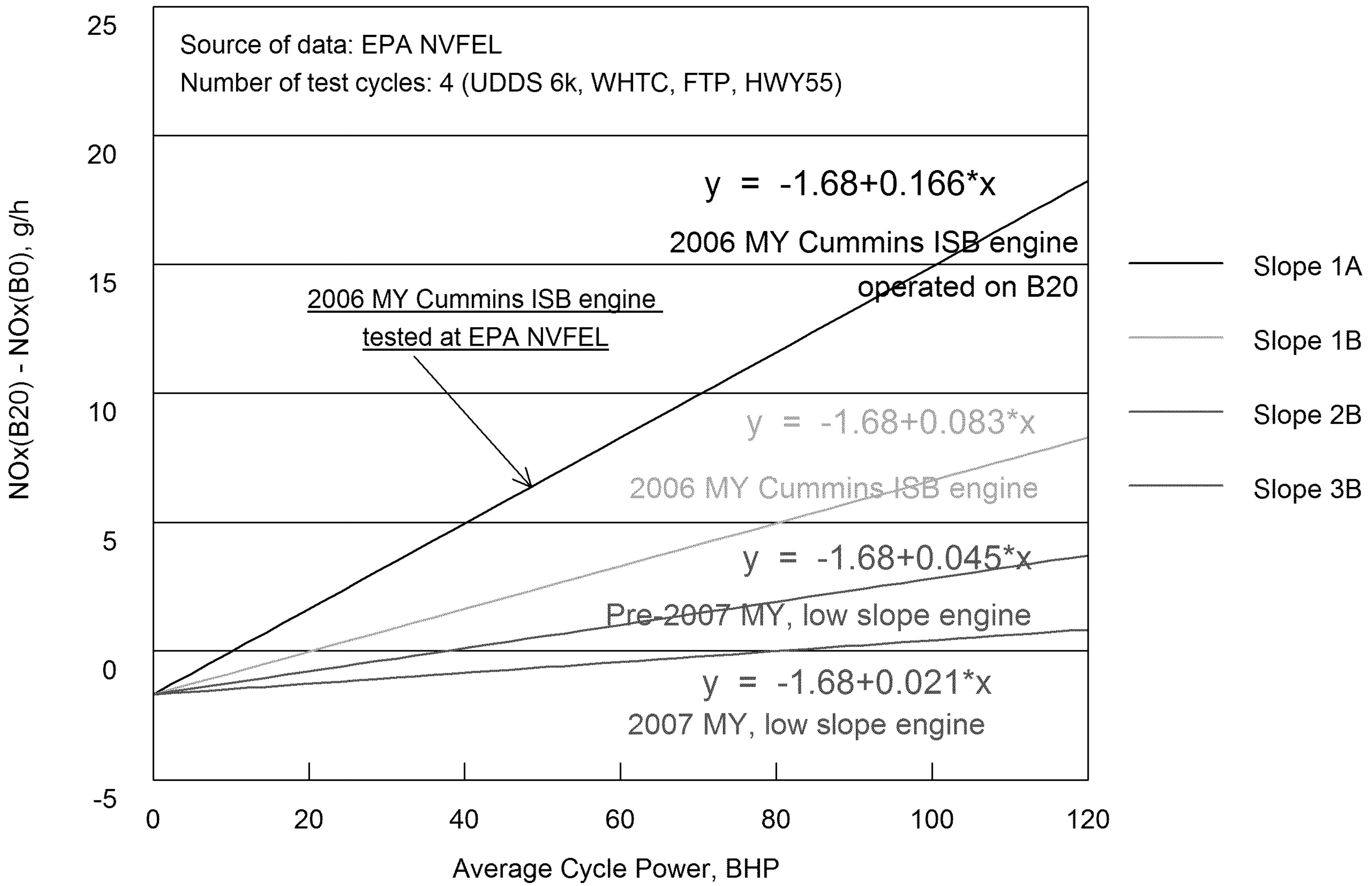


Figure 9: B10 Effects on NOx Emissions



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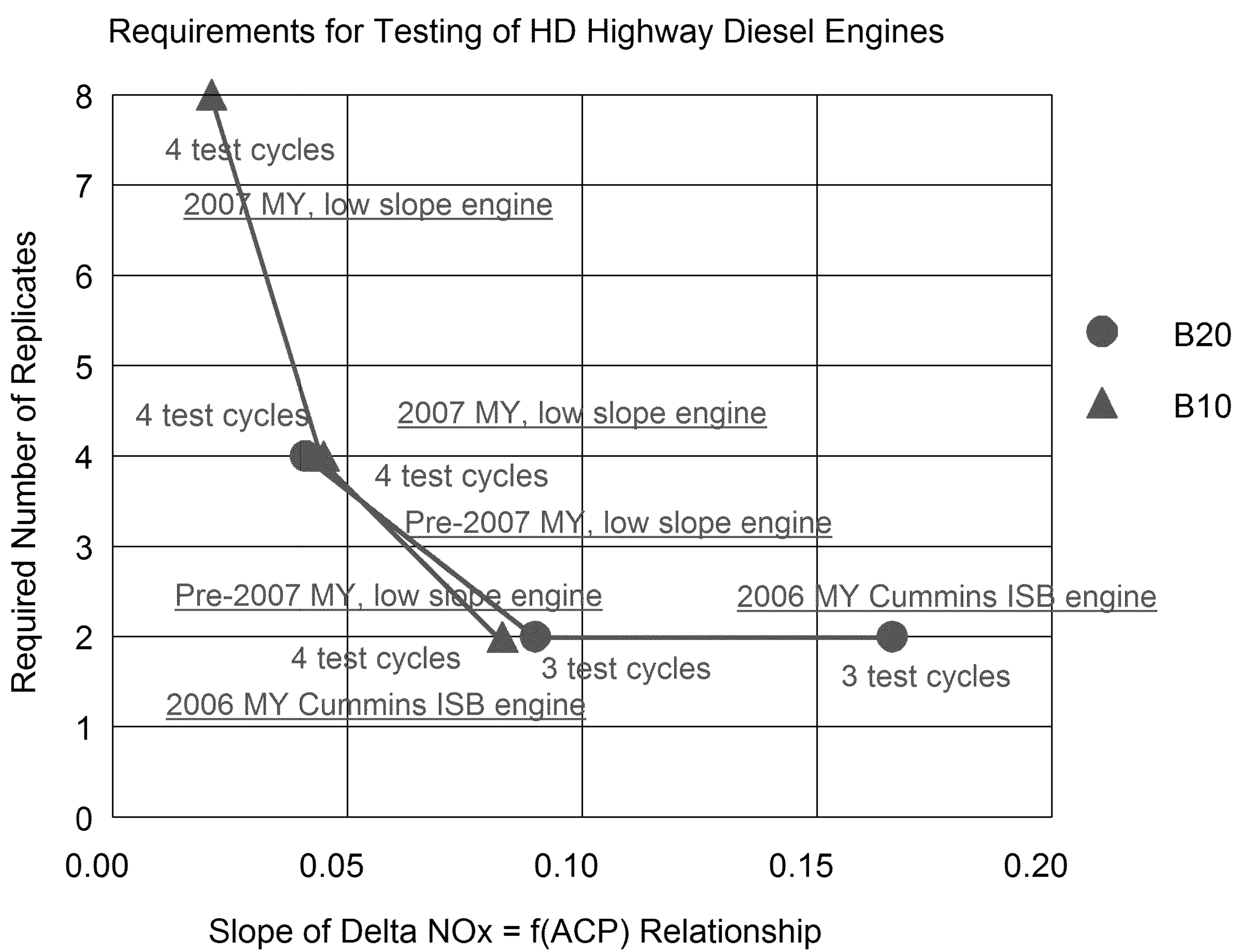
Test Cycles and Test Replicates (Cont'd)

Slopes used in regression analysis:

- Slope 1A: Based on EPA NVFEL data for 2006 MY Cummins ISB engine operated on B20 (0.166)
- Slope 2A: Lowest slope found in NREL B20 data set* (0.166(1/1.85) = 0.090)
- Slope 3A: Lowest NREL slope adjusted to account for 2007 exhaust emission standards (0.166(1/1.85)(1.1/2.4) = 0.041)
- Slope 1B: Slope 1A halved to account for engine operation on B10 instead of B20 (0.083)
- Slope 2B: Slope 2A halved to account for engine operation on B10 instead of B20 (0.045)
- Slope 3B: Slope 3A halved to account for engine operation on B10 instead of B20 (0.021)

* Source: "Effects of Biodiesel Blends on Vehicle Emissions", NREL Milestone Report, October 2006

Figure 10: Number of Test Cycles and Test Replicates



Test Cycles and Test Replicates (Cont'd)

Requirements for Testing of HD Highway Diesel Engines

Emissions Control Technology	B10		B20	
	Number of Test Cycles	Number of Test Replicates	Number of Test Cycles	Number of Test Replicates
Pre-2007 MY	4	4	Min. 3	2
2007 MY	4	8+	4	4
2010+ MY	Need OEM input to produce estimates			

- Technical Subcommittee decided to drop B10 due to its disproportionate effect on the size of the test program
- Linearity of biodiesel impact on NOx emissions below B20 will be demonstrated in separate tests

Test Cycles and Test Replicates (Cont'd)

Recommended number of test cycles:

- 4 test cycles for highway and nonroad engines
  - 4 test cycles can be completed on a fuel in the course of ½ day with minimal effect on cost vs. 3 test cycles
- 3 test cycles for Tier 2 LD vehicles
  - A minimum of 3 test cycles are needed to test linearity of the Delta NOx = f(ACP) relationship

Recommended number of test replicates:

- 3 test replicates for pre-2007 MY highway diesel engines and nonroad engines equipped with similar emissions control technology
  - Number of replicates was increased from 2 to 3 to improve robustness of test data (minimize the effect of mild outliers)
- 4 test replicates for 2007-2009 MY highway diesel engines and nonroad engines equipped with similar emissions control technology
- ? test replicates for Tier 2 LD vehicles (OEM input required)

Specific Test Cycles

- Testing of highway and nonroad engines to be based predominantly on hot test cycles:
  - Minimizes test time and cost
  - However, cold test cycles will be performed as warm-up cycles to generate additional data
- LD vehicles to be tested per standard procedures
- Highway engines:
  - UDDS 6k
  - FTP
  - Test cycle (to be defined); ACP equivalent to 75 mph truck operation
  - Test cycle (to be defined) evenly spaced between the FTP and the 75 mph cycle

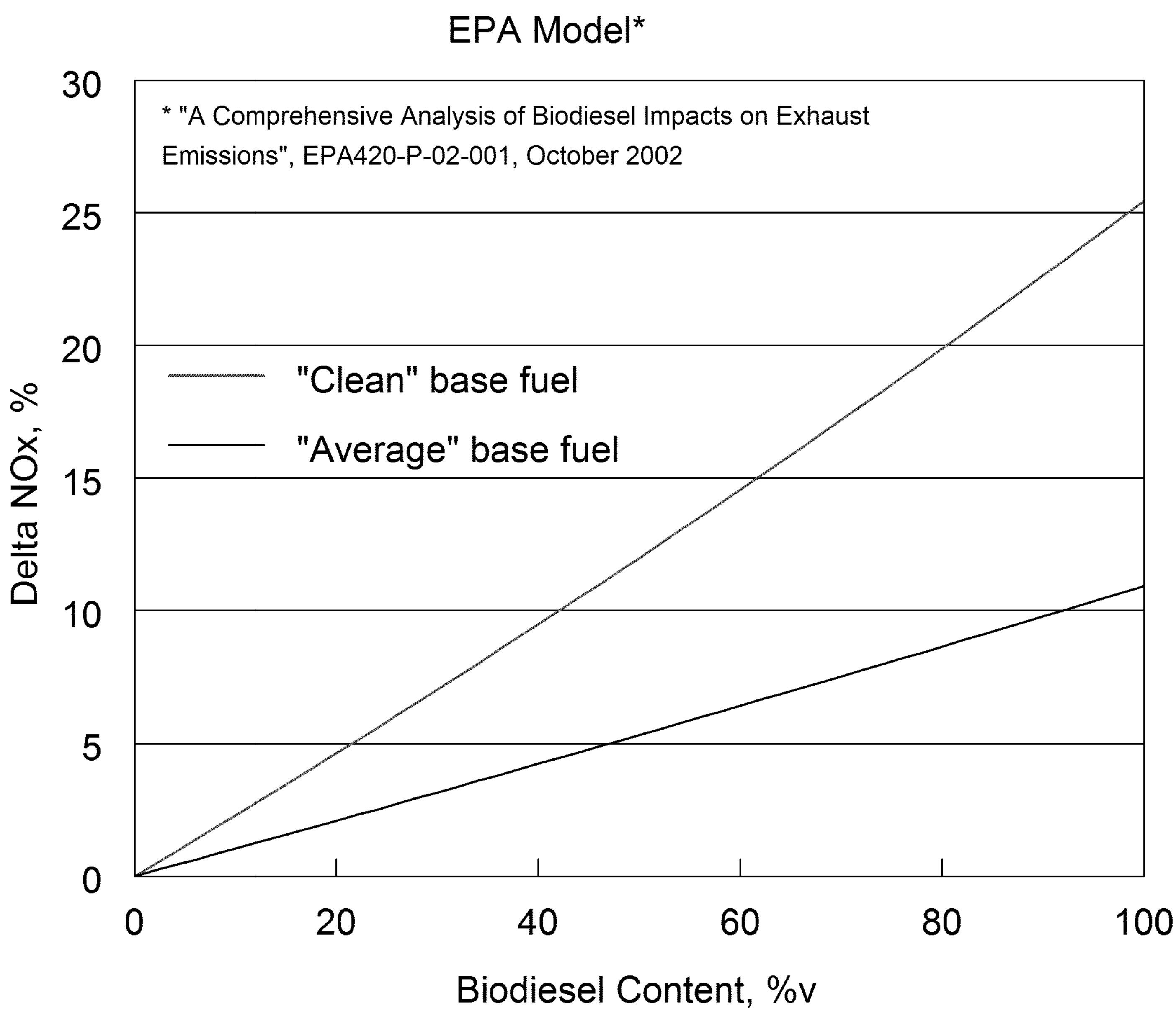
Specific Test Cycles (Cont'd)

- Nonroad engines:
  - UDDS 6k
  - NRTC
  - Test cycle (to be defined) typical of a highway engine of same power rating scaled to ACP level equivalent to 75 mph truck operation
  - Test cycle (to be defined), intermediate ACP
- LD vehicles:
  - FTP
  - CARB Unified Cycle
  - US06

Base Fuels

- The most extensive assessment of base fuel effects on biodiesel NOx impacts available to date is based on the 2002 EPA study:
  - "A Comprehensive Analysis of Biodiesel Impacts on Exhaust Emissions", EPA420-P-02-001, October 2002
- This EPA study divided base fuels into "clean", "average" and "dirty"
  - No base fuels were assigned to "dirty" category
  - Base fuels were considered "clean" if they conformed to requirements for CA diesel fuel or met all of the following conditions:
    - Cetane number > 52
    - Total aromatic content < 25%
    - Specific gravity < 0.84
  - All other fuels were assigned to "average" category
- In the 2002 EPA study, the base fuel was shown to "have significant impact on the correlation between biodiesel concentration and emissions"
- Most recent technical publications support conclusions of the 2002 EPA study

Figure 11: Base Fuel Effects on Biodiesel NOx Impacts



Base Fuels (Cont'd)

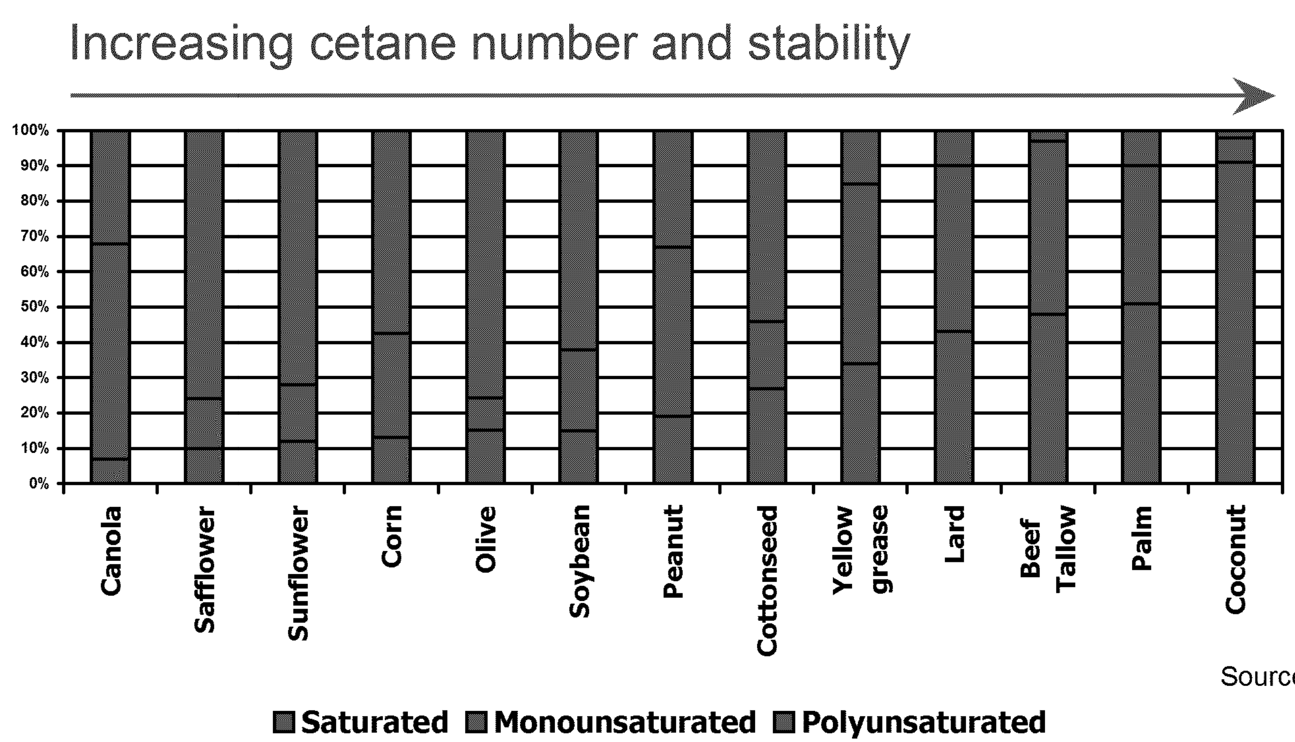
- Base fuels to cover cetane number, density and aromatic content ranges typical of U.S. No. 2 diesel fuel
  - Changes in mono-, poly- and total aromatic content to be directly linked to changes in density
  - Base fuel property range assumptions will be updated based on winter 2006/2007 diesel fuel quality surveys
  - One of the base fuels will be a "typical" CARB diesel fuel
- S ≤ 15 ppm
- T90 to be controlled within a predefined range, e.g. 590 – 610 ºF
- Base fuels must meet D975 requirements

Base Fuels (Cont'd)

- Base fuels must not contain any cetane improvers
  - ~75% of U.S. diesel fuel contains no cetane improvers
  - ~50% of CA diesel fuel contains no cetane improvers
  - Wide variation in cetane improver impacts on NOx emissions from diesel engines operated on biodiesel fuels reported in technical literature
    - Treat rates used in cetane improver/biodiesel studies are much higher than in market fuels
  - Clarification of cetane improver impacts in biodiesel fuels requires a separate investigation
- The use of other performance additives in finished blends must be minimized, e.g. lubricity improver

Biodiesel Composition

- Composition mirrors the fatty acid content of the feedstock
- Animal fats, palm, coconut oils are more highly saturated
  - higher CN, higher cloud point
- Fuels high in polyunsaturates are less stable



Source: NREL

Biodiesels

- Test two biodiesels spanning the composition/property scale, i.e.:
  - Soy-derived
    - Currently dominant in the U.S.
    - High in unsaturates
  - Animal fat-derived
    - High in saturates
  - Focus on soy-derived biodiesel
  - Animal fat-based biodiesel will only be blended into one base fuel
    - This approach will enable interpolation without excessively enlarging the test program
- Additional biodiesel(s) may be tested by CARB in 3 engines and 4 vehicles
- All biodiesels used in this program must meet the following requirements;
  - D6751
  - BQ9000
  - Other ?

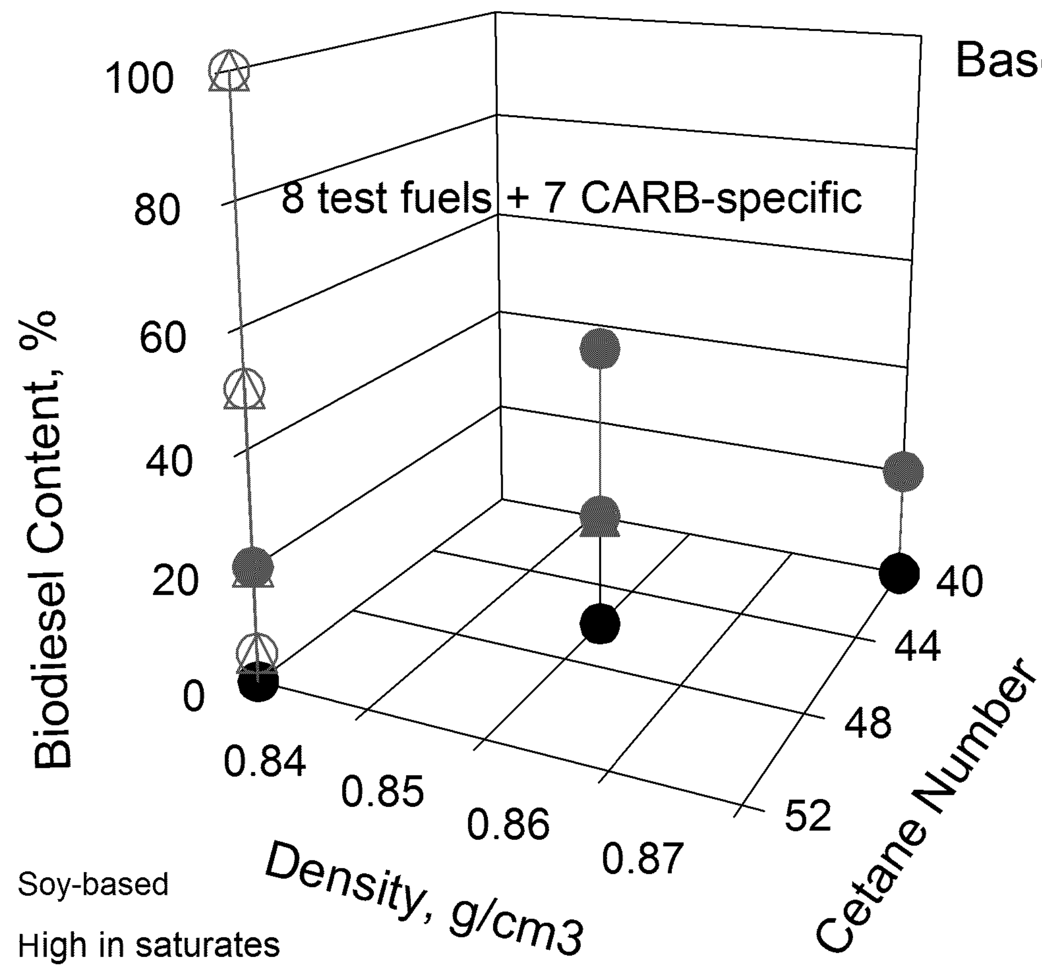
Biodiesel Test Fuels

- Focus on B20 blends
  - Linearity of biodiesel impacts on NOx emissions below B20 may be evaluated in a limited scope study, such as the following:
    - Number of test engines: 1
    - MY of test engine: 2002 - 2006
    - Test cycle: High load cycle, such as HWY55, to increase the likelihood of achieving statistically significant results for the least amount of testing
    - Base fuel: ULS “average” US diesel fuel
    - Biodiesel: Soy-derived
    - Biodiesel content levels investigated: B5, B10 and B20
    - Estimated cost: $70,000
    - If significant nonlinearity is observed, additional testing can be added
- B5, B20, B50 and B100 blends will be tested by CARB in 3 engines and 4 vehicles

Biodiesel Test Fuels (Cont'd)

- B0 – B20 blends must meet D975 requirements
  - Per ASTM discussions of proposed B20 specification, D975 max. T90 specification may be exceeded by 5°C
- S ≤ 15 ppm
- The use of performance additives in biodiesel fuels must be kept to a minimum
- Additional issues requiring resolution:
  - Biodiesel fuel storage
    - Storage stability control
    - Monitoring of biodiesel fuel quality in storage

Fuel Matrix



Soy-based

High in saturates

Base fuel

Soy-based, tested in CARB engines/vehicles only

High in saturates, tested in CARB engines/vehicles only

Base fuel property ranges:

- Density: 0.83 – 0.87 g/cm3
- Cetane number: 40 - 52
- Monoaromatics: 18 – 31%
- Polyaromatics: 2 - 9%
- Total Aromatics: 20 – 40%
- T90: 590 – 610 °F
- Base fuel property ranges will be updated based on winter 2006/2007 diesel fuel surveys

Measured Exhaust Constituents

- THC, NMHC, CO, NO_2, NOx, PM, SOF (Soxhlet)
- CO_2, N_2O, NH_4
- C1 – C12 unregulated emissions
- In-depth characterization of unregulated emissions conducted on a limited set of samples, per proposed CARB Program
- Second-by-second THC, NMHC, CO, NO_2, NOx

Emissions Test Sequence

Example: 2007-2009 MY HD Diesel Engine

Number of test fuels in a set: 3 (one B0 and two B20 fuels)

Number of test replicates per fuel: 4

Day 1		Day 2		Day 3		Day 4		Day 5		Day 6	
Fuel	Cycle	Fuel	Cycle	Fuel	Cycle	Fuel	Cycle	Fuel	Cycle	Fuel	Cycle
Base	A	2	A	3	A	Base	A	2	A	3	A
	B		B		B		B		B		B
	C		C		C		C		C		C
	D		D		D		D		D		D
2	A	3	A	Base	A	2	A	3	A	Base	A
	B		B		B		B		B		B
	C		C		C		C		C		C
	D		D		D		D		D		D

- 4 test cycles
- Test cycles performed in random order
- Sequence takes into account day-to-day and AM/PM variability
- Time still available to repeat a cycle, if test quality criteria not met

Program Cost Estimate

Program	Test Engines/Vehicles	Number of Engines/ Vehicles	Cost of Exhaust Emission Testing, $M	Cost of Unregulated Emission Measurements, $M	Fuel Cost, $M	Statistical Analysis, $M	Engine and Vehicle Cost, $M	Total, $M
Base	Engines (includes 3 nonroad)	21	Ex. 4 - CBI					
	LD Vehicles	3						
CARB	Engines	3						
	Vehicles	4						
							Grand Total:	Ex. 4 - CBI

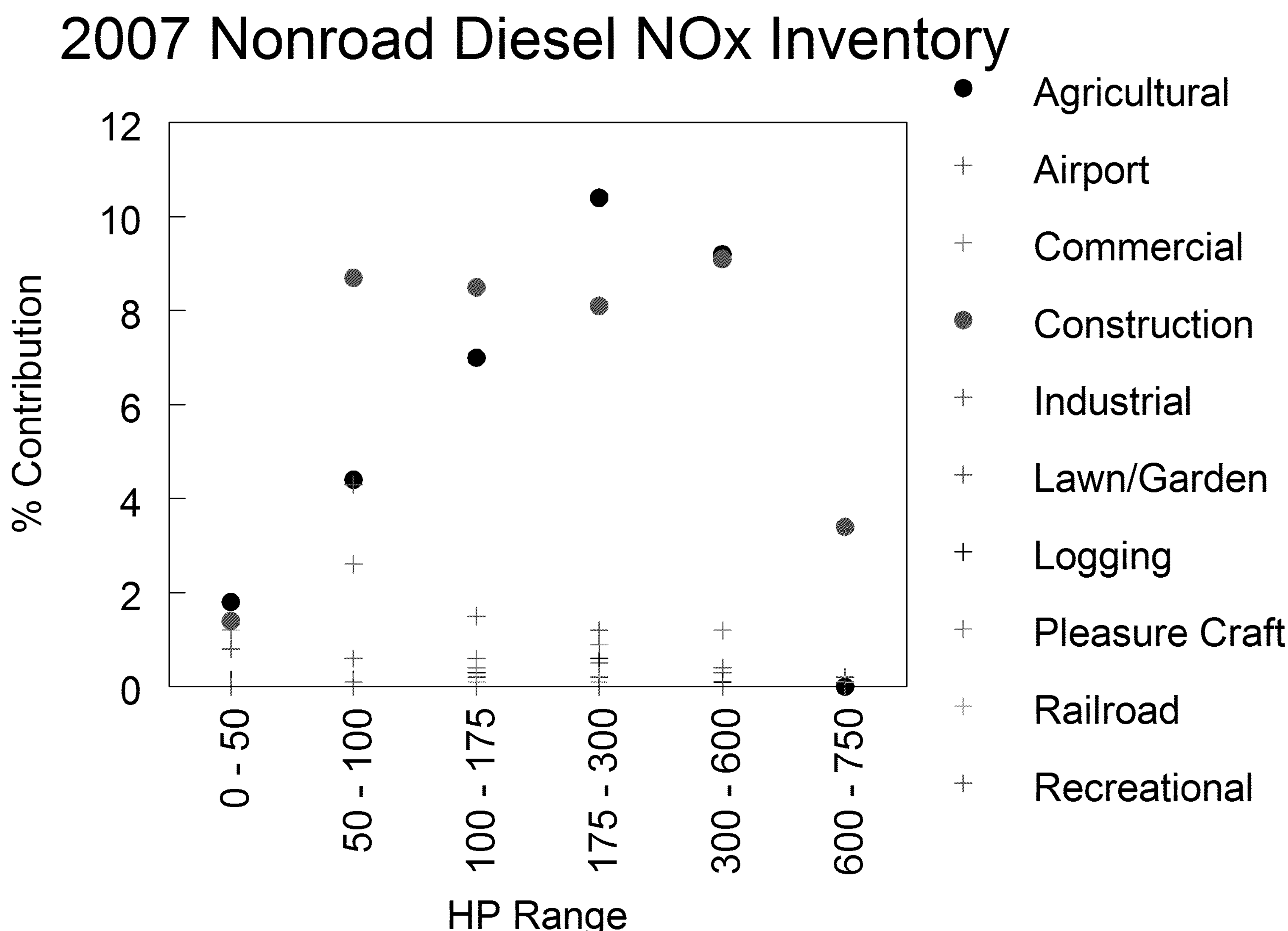
Funding for CBET Program

Stakeholder	Cash Contributions, $M	In-Kind Contributions, $M	Total Contributions, $M
EPA**			
NBB			
CARB			
EMA			
AAM			
API			
All Stakeholders	**0**	**0**	**0**
		Total Needed:	5.11
		Shortfall:	**(5.11)**

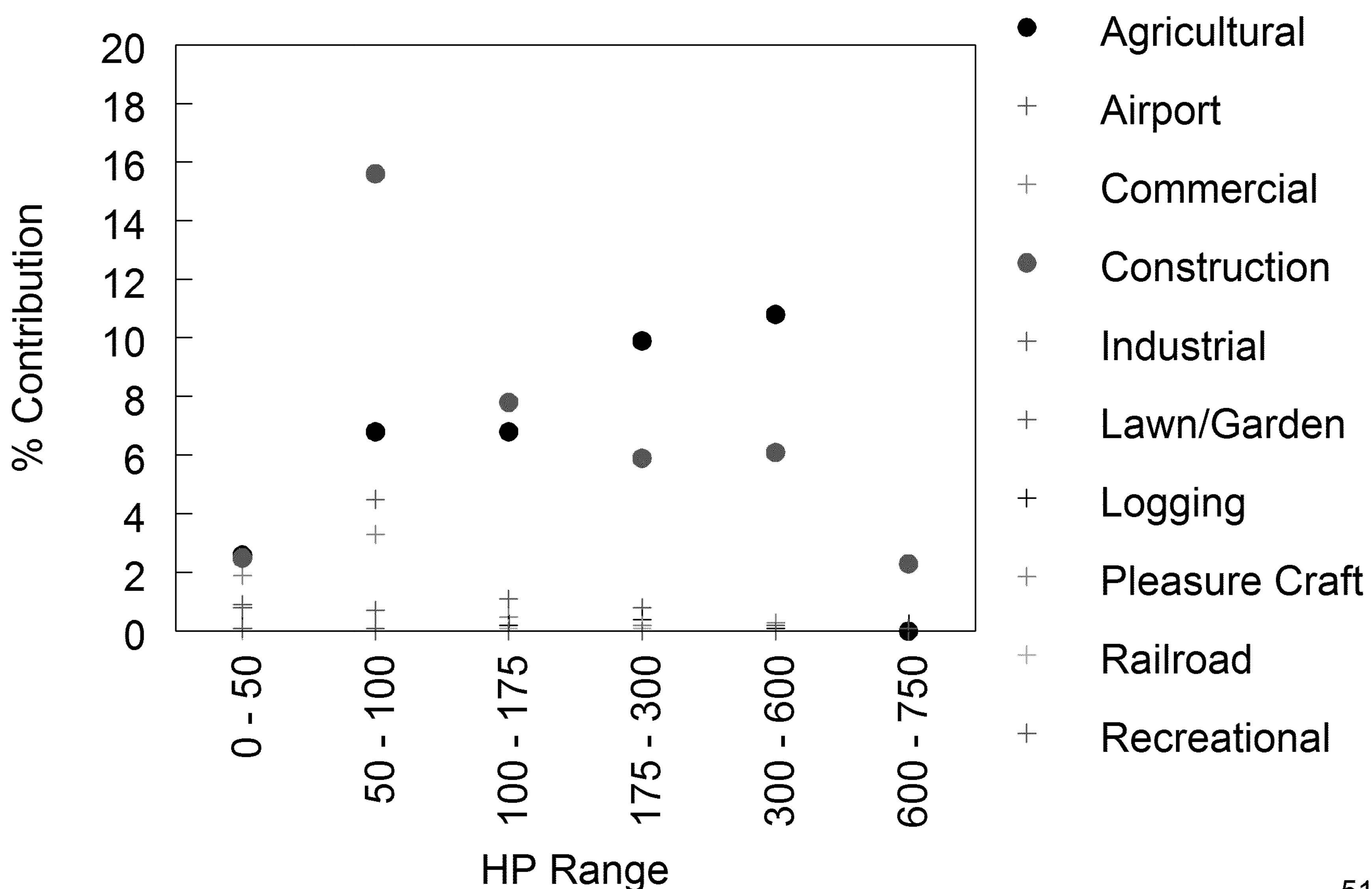
** EPA testing 3 engines

Back-up Slides

Vehicle Class	Vehicle Class Description
LDDV	Light-Duty Diesel Vehicles (Passenger Cars)
LDDT	Light-Duty Diesel Trucks 1, 2, 3 and 4 (0-8,500 lbs. GVWR)
2BHDDV	Class 2b Heavy-Duty Diesel Vehicles (8501-10,000 lbs. GVWR)
LHDDV	Class 3, 4 and 5 Heavy-Duty Diesel Vehicles (10,001-19,500 lbs. GVWR)
MHDDV	Class 6 and 7 Heavy-Duty Diesel Vehicles (19,501-33,000 lbs. GVWR)
HHDDV	Class 8a and 8b Heavy-Duty Diesel Vehicles (33,001- >60,000 lbs. GVWR)
BUSES	Diesel Transit, Urban and School Buses


2007 Nonroad Diesel NOx Inventory
% Contribution
0
2
4
6
8
10
12
0 - 50
50 - 100
100 - 175
175 - 300
300 - 600
600 - 750
HP Range
Agricultural
Airport
Commercial
Construction
Industrial
Lawn/Garden
Logging
Pleasure Craft
Railroad
Recreational

2007 Nonroad Diesel PM Inventory



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EPA's Preliminary Investigation

- Objective: Elucidate the effect of test cycle and average cycle load on biodiesel NOx effect in order to guide the development of the collaborative program
- Conducted in December 2006 and January 2007
- Test engine: MY 2006 Cummins ISB
- Base fuel: ULS Phillips certification diesel
- Biodiesel blendstock: Soy-derived
- Biodiesel blend levels: B20 and B50
- Transient Engine Test Cycles:
  - HD FTP
  - Urban Dynamometer Driving Schedule (UDDS, two load levels)
  - CARB highway cycle developed for use in CRC program E-55 (HWY55)
  - World Harmonized Test Cycle (WHTC)
- Test laboratory: NVFEL

Figure 1: B20 and B50 Effects on NOx Emissions
MY 2004 Cummins ISB Engine

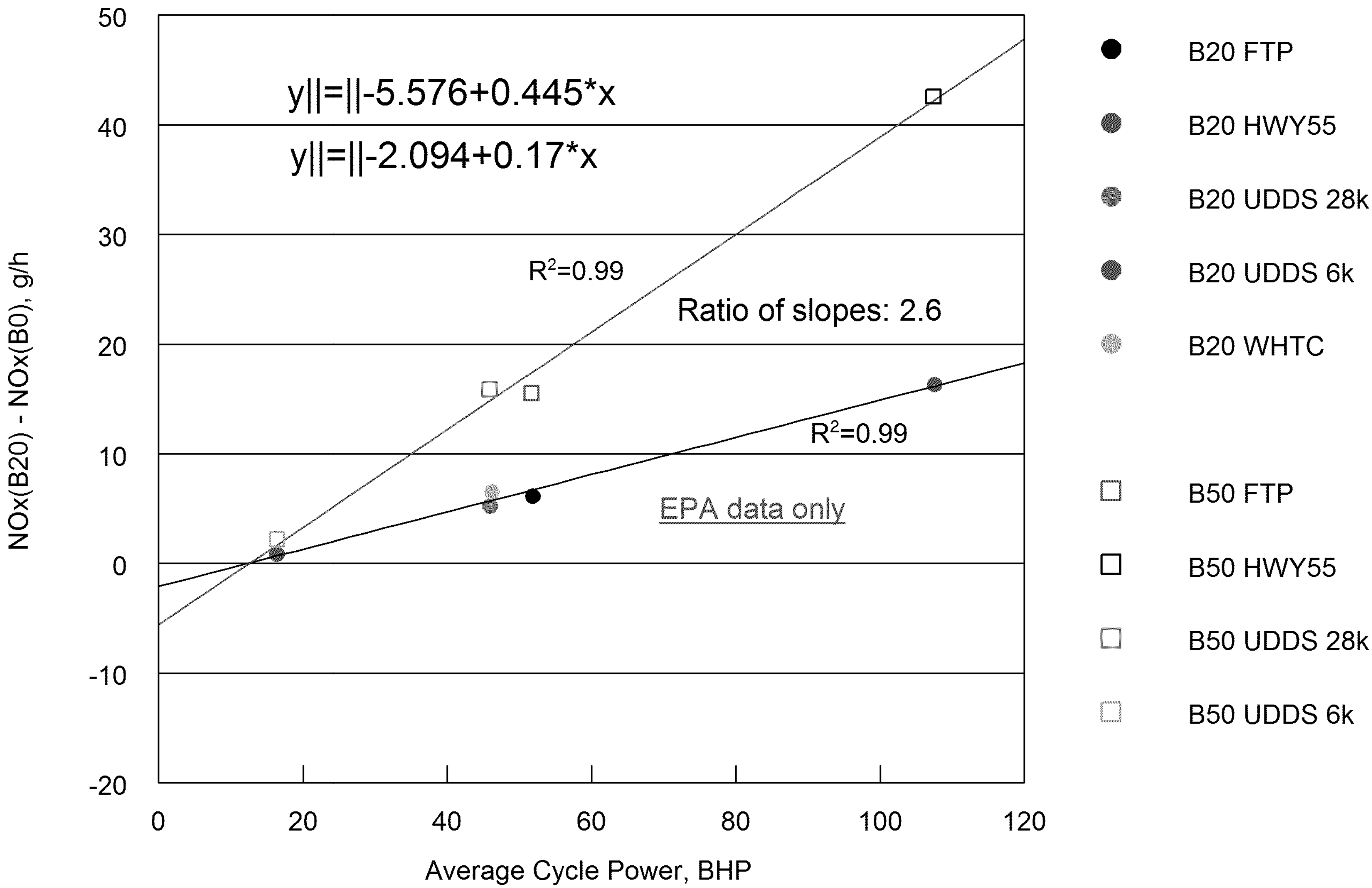

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Figure 2: B20 and B50 Effects on NOx Emissions
MY 2004 Cummins ISB Engine

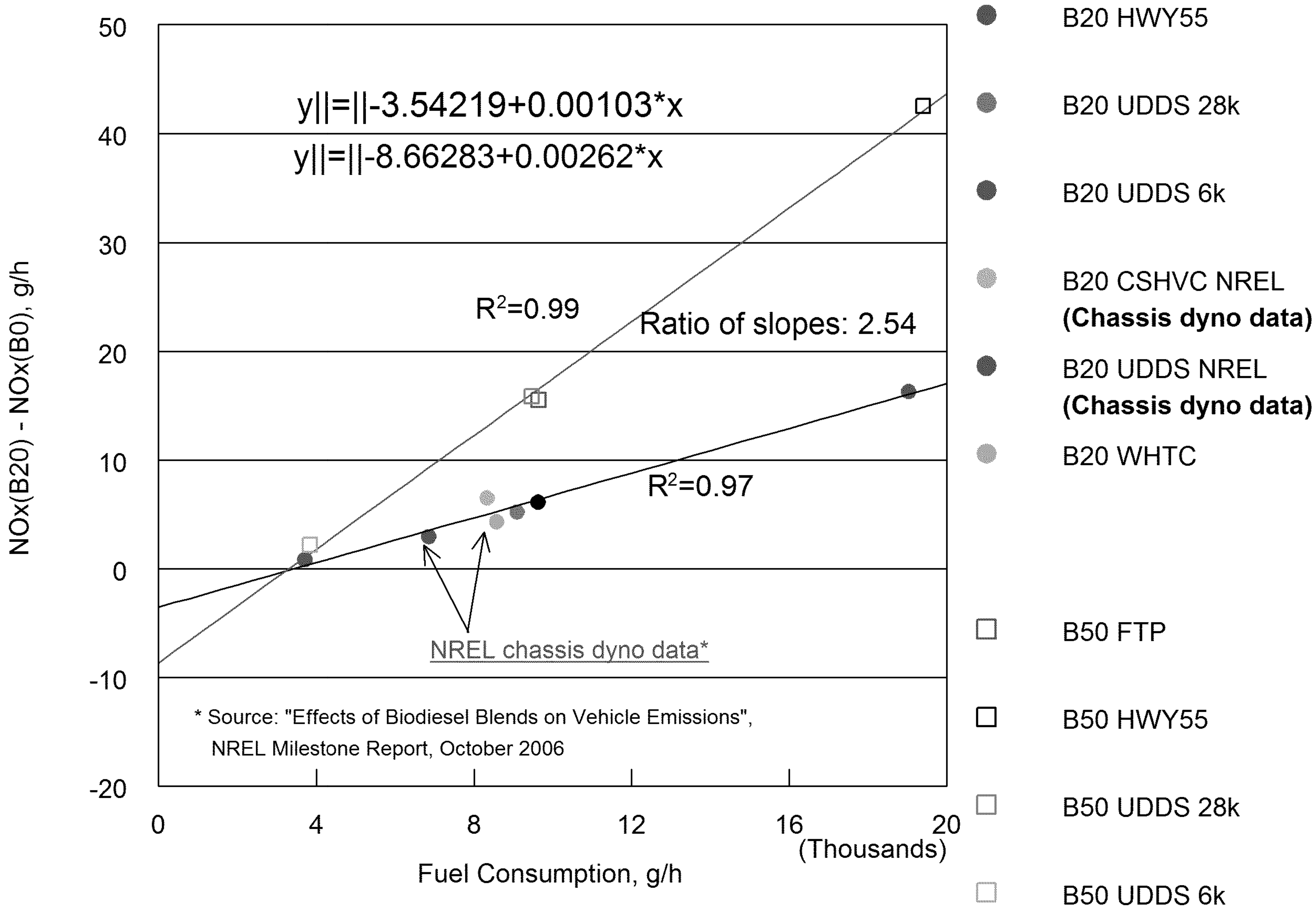


Figure 3: B20 Effects on NOx Emissions

EPA Engine Dyno Data and NREL Chassis Dyno Data*

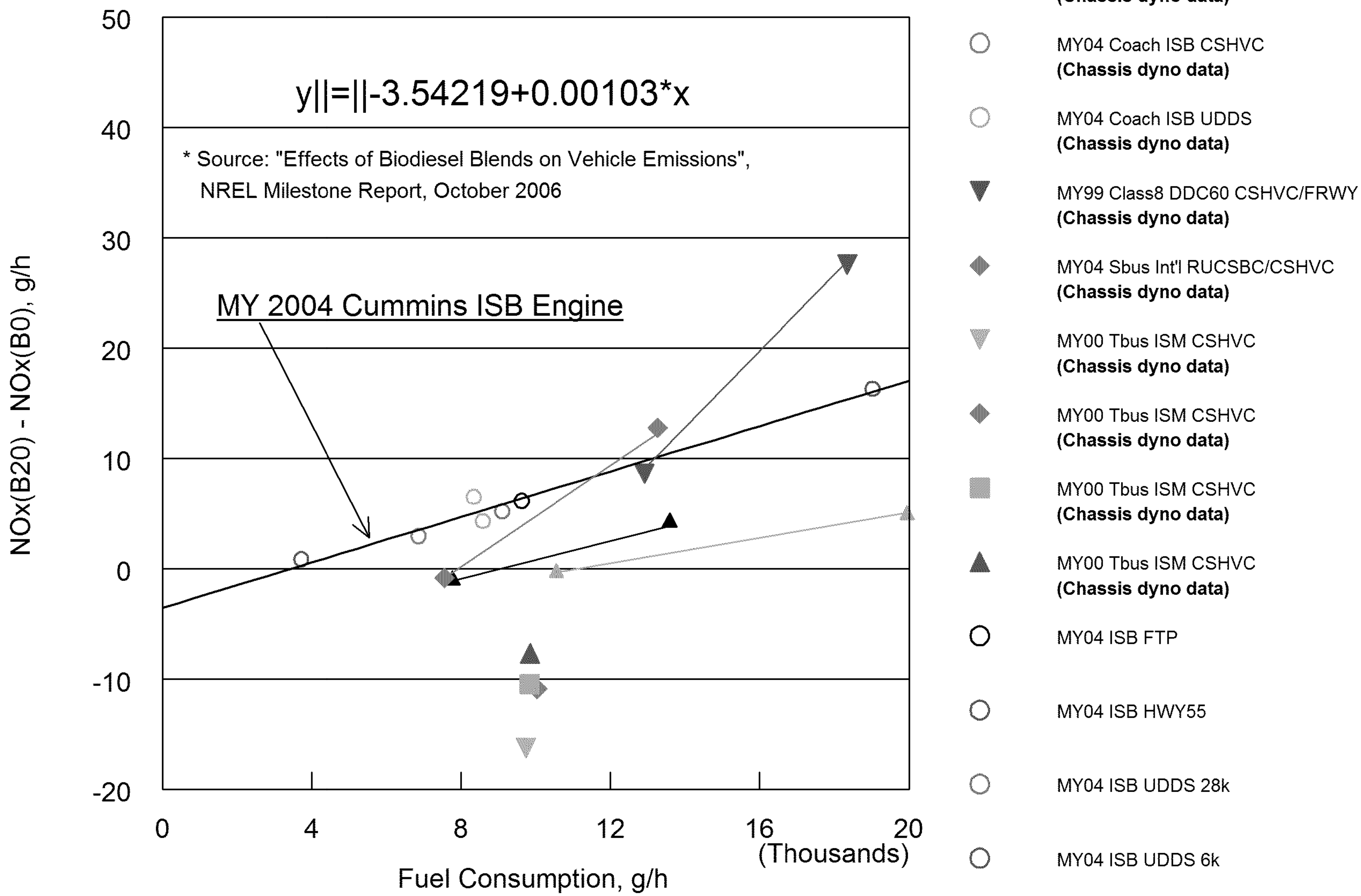
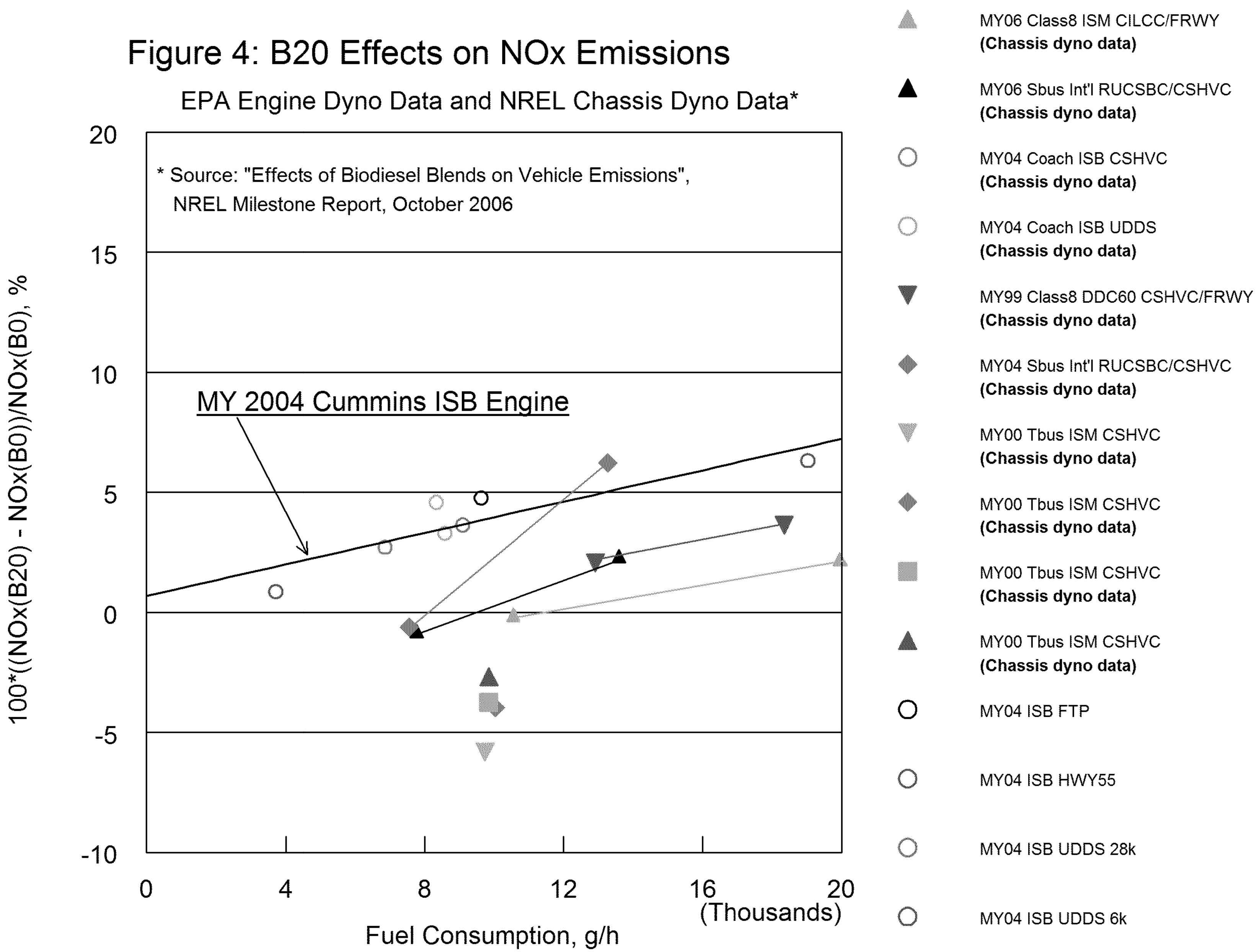


Figure 4: B20 Effects on NOx Emissions



EPA's Preliminary Investigation (Cont'd)

Conclusions:

- Biodiesel effect on NOx emissions was directly proportional to:
  - Average cycle load
  - Biodiesel content (Tested at B0, B20 and B50 levels)
- The effect of "test cycle" on NOx emissions was relatively small
  - NREL chassis testing in line with EPA engine tests
- Conclusions based on exhaust emission testing of one Cummins ISB engine by the EPA and chassis test data generated by NREL
- Testing as a part of a broader program may confirm the observed effects